POSTER SESSION

Session Title: PP31D. Younger Dryas Boundary: Extraterrestrial Impact or Not? | Posters

Session Type: Poster

Chair: Philippe F Claeys
Chair: Mark Boslough

Location: Poster Hall (Moscone South)

Start time: Wed, Dec 16 - 8:00 AM

PP31D-1381. What Caused the Younger Dryas? An Assessment of Existing Hypotheses. *A. E. Carlson; P. U. Clark* View Pres.	Wed, Dec 16 8:00 AM	No itinerary selected
PP31D-1382. Human Population Decline in North America during the Younger Dryas. *D. G. Anderson; A. C. Goodyear; T. W. Stafford, Jr.; J. Kennett; A. West* View Pres.	Wed, Dec 16 8:00 AM	No itinerary selected
PP31D-1383. Problems with the Younger Dryas Boundary (YDB) Impact Hypothesis. *M. Boslough* View Pres.	Wed, Dec 16 8:00 AM	No itinerary selected
PP31D-1384. Oblique impacts into low impedance layers. *A. M. Stickle; P. H. Schultz* View Pres.	Wed, Dec 16 8:00 AM	No itinerary selected
PP31D-1385. Beringian Megafaunal Extinctions at ~37 ka B.P.: Do Micrometeorites Embedded in Fossil Tusks and Skulls Indicate an Extraterrestrial Precursor to the Younger Dryas Event?. *J. T. Hagstrum; R. B. Firestone; A. West* View Pres.	Wed, Dec 16 8:00 AM	No itinerary selected
PP31D-1386. Evidence of four prehistoric supernovae <250 pc from Earth during the past 50,000 years. *R. B. Firestone* View Pres.	Wed, Dec 16 8:00 AM	No itinerary selected
PP31D-1387. Geomorphology Of Possible Younger Dryas Boundary Impact Structure. *M. E. Davias; J. L. Gilbride* View Pres.	Wed, Dec 16 8:00 AM	No itinerary selected
PP31D-1388. Positive anomaly in platinum group elements and the presence of shocked diamonds: Two question marks at the Younger Dryas . *P. F. Claeys; D. Schryvers; H. Tian; S. Goderis* View Pres.	Wed, Dec 16 8:00 AM	No itinerary selected
PP31D-1389. The platinum group metals in Younger Dryas Horizons are terrestrial. *Y. Wu; E. Wikes; J. Kennett; A. West; M. Sharma* View Pres.	Wed, Dec 16 8:00 AM	No itinerary selected
PP31D-1390. Field-Analytical approach of land-sea records for elucidating the Younger Dryas Boundary syndrome. *T. Ge; M. M. COURTY; F. Guichard* View Pres.	Wed, Dec 16 8:00 AM	No itinerary selected
PP31D-1391. Cometary airbursts and atmospheric chemistry: Tunguska and a candidate Younger Dryas event. *A. Melott* View Pres.	Wed, Dec 16 8:00 AM	No itinerary selected
PP31D-1392. Nanodiamonds and Carbon Spherules from Tunguska, the K/T Boundary, and the Younger Dryas Boundary Layer. *J. H. Wittke; T. E. Bunch; A. West; J. Kennett; D. J. Kennett; G. A. Howard* View Pres.	Wed, Dec 16 8:00 AM	No itinerary selected
PP31D-1393. Wildfires, Soot and Fullerenes in the 12,900 ka Younger Dryas boundary layer in North America. *L. Becker; R. J. Poreda; J. Kennett; D. J. Kennett; J. M. Erlandson; A. West* View Pres.	Wed, Dec 16 8:00 AM	No itinerary selected
PP31D-1394. Cold Climate Related Structural Sinks Accommodate Unusual Soil Constituents, Pinelands National Reserve, New Jersey, USA.. *M. Demitroff; M. A. LeCompte; B. N. Rock* View Pres.	Wed, Dec 16 8:00 AM	No itinerary selected
PP31D-1395. Rockyhock and Kimbel Carolina Bays: Extraterrestrial Impact or Terrestrial Genesis?. *M. A. LeCompte; B. D. Branch; L. Barnes; C. Hall* View Pres.	Wed, Dec 16 8:00 AM	No itinerary selected
PP31D-1396. An Independent Evaluation of the Younger Dryas Extraterrestrial Impact Hypothesis. *T. A. Surovell; V. T. Holliday* View Pres.	Wed, Dec 16 8:00 AM	No itinerary selected

PP31D-1397. Evidence for Widespread Biomass-Burning at the Younger Dryas Boundary at 12.9 ka. *J. Kennett; P. A. Mayewski; A. West; T. E. Bunch; T. W. Stafford; W. S. Wolbach* View Pres.	Wed, Dec 16 8:00 AM	No itinerary selected
PP31D-1398. Climatic Control of Biomass Burning During the Last Glacial-Interglacial Transition. *J. R. Marlon; P. J. Bartlein; A. Daniau; S. P. Harrison* View Pres.	Wed, Dec 16 8:00 AM	No itinerary selected
PP31D-1399. Fire regimes during the last glacial. *A. Daniau; S. P. Harrison; P. J. Bartlein* View Pres.	Wed, Dec 16 8:00 AM	

ID#	PP31D-1381
Location:	Poster Hall (Moscone South)
Time of Presentation:	Dec 16 8:00 AM - 12:20 PM

What Caused the Younger Dryas? An Assessment of Existing Hypotheses

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The Younger Dryas cold event (~12.9-11.7 ka) has long been viewed as the canonical abrupt climate event. It was originally attributed to northward retreat of the southern Laurentide Ice Sheet (LIS) and eastward routing of Lake Agassiz from the Mississippi River to the St. Lawrence River, with the attendant freshening of the North Atlantic causing a reduction in Atlantic meridional overturning circulation (AMOC) strength. This original hypothesis has now been questioned based on 1) LIS model simulations that suggest an abrupt Arctic discharge of freshwater as the trigger, and 2) new dates from the outlets of Lake Agassiz, which are interpreted as indicating that the lake had no outlet during most of the Younger Dryas.
With regards to Arctic freshwater forcing, one LIS model simulation produced a 0.09 Sverdrup (Sv) pulse of freshwater to the Arctic Ocean at the start of the Younger Dryas forced by a linearly interpolated Greenland ice-core climate scheme. However, this pulse lasted <300 yrs, which is too short to explain the 1200-yr long event in the most advanced atmosphere-ocean general circulation models. The negligible sea-level rise that occurred during the Younger Dryas also rules out a significantly longer forcing from LIS melting. Finally, existing paleoceanographic records show no evidence of an increase in North American freshwater discharge to the Arctic Ocean at the start of the Younger Dryas, thus strongly questioning the Arctic-forcing hypothesis. Recent dating efforts on the Lake Agassiz outlets have mainly used minimum limiting radiocarbon dates, exclusively in the case of the

eastern outlet where Lake Agassiz freshwater was supposedly routed during the Younger Dryas. A strict interpretation of these dates demonstrates, however, that they are not in conflict with the original routing hypothesis. The oldest minimum limiting macrofossil date constraining the southern outlet requires abandonment prior to ~12.8 ka, with the oldest macrofossil date from the eastern outlet indicating it was open prior to ~12.6 ka (potentially prior to ~13 ka based on the oldest bulk radiocarbon date). This chronology agrees with runoff proxies from the mouths of the Mississippi and St. Lawrence Rivers, where multiple planktonic oxygen-isotope records indicate the abandonment of the southern outlet and five independent geochemical runoff proxies record the routing of Lake Agassiz freshwater to the eastern outlet at the start of the Younger Dryas. Geochemical modeling of these latter proxies suggests freshwater discharge increases to the North Atlantic of 0.06-0.12 Sv for the duration of the Younger Dryas, which is sufficient forcing to explain this cold event.
AMOC-sensitive proxy records show Younger Dryas-like events during earlier deglaciations that were forced by similar magnitude changes in boreal summer insolation as during the last deglaciation, arguing against a unique bolide forcing of the Younger Dryas.

ID#	PP31D-1382
Location:	Poster Hall (Moscone South)
Time of Presentation:	Dec 16 8:00 AM - 12:20 PM

Human Population Decline in North America during the Younger Dryas

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There is ongoing debate about a possible human population decline or contraction at the onset of the Younger Dryas (YD) at 12.9 ka. We used two methods to test whether the YD affected human population levels:

(1) frequency analyses of Paleoindian projectile points, and (2) summed probability analyses of radiocarbon (^{14}C) dates. The results suggest that a significant decline or reorganization of human populations occurred at 12.9 ka, continued through the initial centuries of the YD chronozone, then rebounded by the end of the YD. **FREQUENCY ANALYSES:** This method employed projectile point data from the Paleoindian Database of the Americas (PIDBA, http://pidba.utk.edu). We tallied diagnostic projectile points and obtained larger totals for Clovis points than for immediately post-Clovis points, which share an instrument-assisted fluting technique, typically using pressure or indirect percussion. Gainey, Vail, Debert, Redstone, and Cumberland point-styles utilized this method and are comparable to the Folsom style. For the SE U.S., the ratio of Clovis points (n=1993) to post-Clovis points (n=947) reveals a point decline of 52%. For the Great Plains, a comparison of Clovis and fluted points (n=4020) to Folsom points (n=2527) shows a point decline of 37%, which may translate into a population contraction of similar magnitude. In addition, eight major Clovis lithic quarry sites in the SE U.S. exhibit little to no evidence for immediate post-Clovis occupations, implying a major population decline. **SUMMED PROBABILITIES:** This method involved calibrating relevant ^{14}C dates and combining the probabilities, after which major peaks and troughs in the trends are assumed to reflect changes in human demographics. Using ^{14}C dates from Buchanan et al. (2008), we analyzed multiple regions, including the Southeast and Great Plains. Contrary to Buchanan et al., we found an abrupt, statistically significant decline at 12.9 ka, followed 200 to 900 years later by a rebound in the number of dates. The decline at the YD onset was more than 50%, similar in magnitude to the decline in Clovis-Folsom point ratios. While calibration and sampling factors may affect the trends, this abrupt decline is large and requires explanation. **SUMMARY:** Even though correlation does not equate with causation, the coeval YD decline in both points and ^{14}C dates appears linked to significant changes in climate and biota, as represented by the megafaunal extinction. While the causes of the YD remain controversial, a human population decline appears to have occurred, at least across parts of North America. Furthermore, the YD onset is associated with the abrupt replacement of Clovis by regional or subregional scale cultural traditions, potentially reflecting decreased range mobility and increased population isolation. Projectile point distributions and summed probability analyses, we argue, are potentially useful approaches for exploring demographic changes at regional scales.

ID#	PP31D-1383
Location:	Poster Hall (Moscone South)
Time of Presentation:	Dec 16 8:00 AM - 12:20 PM

Problems with the Younger Dryas Boundary (YDB) Impact Hypothesis

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One breakthrough of 20th-century Earth science was the recognition of impacts as an important geologic process. The most obvious result is a crater. There are more than 170 confirmed terrestrial impact structures with a non-uniform spatial distribution suggesting more to be found. Many have been erased by tectonics and erosion. Deep water impacts do not form craters, and craters in ice sheets disappear when the ice melts. There is growing speculation that such hidden impacts have caused frequent major environmental events of the Holocene, but this is inconsistent with the astronomically-constrained population of Earth-crossing asteroids.

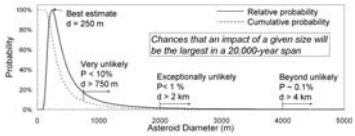
Impacts can have consequences much more significant than excavation of a crater. The K/T boundary mass extinction is attributed to the environmental effects of a major impact, and some researchers argue that other extinctions, abrupt climate changes, and even civilization collapses have resulted from impacts. Nuclear winter models suggest that 2-km diameter asteroids exceed a "global catastrophe threshold" by injecting sufficient dust into the stratosphere to cause short-term climate changes, but would not necessarily collapse most natural ecosystems or cause mass extinctions. Globally-catastrophic impacts recur on timescales of about one million years.

The 1994 collision of Comet Shoemaker-Levy 9 with Jupiter led us recognize the significance of terrestrial airbursts caused by objects exploding violently in Earth’s atmosphere. We have invoked airbursts to explain rare forms of non-volcanic glasses and melts by using high-resolution computational models to improve our understanding of atmospheric explosions, and have suggested that multiple airbursts from fragmented impactors could be responsible for regional effects.

Our models have been cited in support of the widely-publicized YDB impact hypothesis. Proponents claim that a broken comet exploded over North America, with some fragments cratering the Laurentide Ice Sheet. They suggest an abrupt climate change caused by impact-triggered meltwater forcing, along with massive wildfires, resulted in megafaunal extinctions and collapse of the Clovis culture.

We argue that the physics of fragmentation, dispersion, and airburst is not consistent with the hypothesis; that observations are no more compatible with impact than with other causes; and that the probability of the scenario is effectively nil. Moreover, millennial-scale climate events are far more frequent than catastrophic impacts, and pose a much greater threat to humanity.

Sandia is a multiprogram laboratory operated by Sandia Corp, a Lockheed Martin Company, for the US DOE under Contract DE-AC04-94AL85000.



Probability density for largest asteroid impact since Last Glacial Maximum based on power-law size distribution. Comets are orders of magnitude less likely. Grazing trajectory or recent fragmentation further reduces probability.

ID#	PP31D-1384
Location:	Poster Hall (Moscone South)
Time of Presentation:	Dec 16 8:00 AM - 12:20 PM

Oblique impacts into low impedance layers

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Planetary impacts occur indiscriminately, in all locations and materials. Varied geologic settings can have significant effects on the impact process, including the coupling between the projectile and target, the final damage patterns and modes of deformation that occur. For example, marine impact craters are not identical to impacts directly into bedrock or into sedimentary materials, though many of the same fundamental processes occur. It is therefore important, especially when considering terrestrial impacts, to understand how a low impedance sedimentary layer over bedrock affects the deformation process during and after a hypervelocity impact. As a first step, detailed comparisons between impacts and hydrocode models were performed. Experiments performed at the NASA Ames Vertical Gun Range of oblique impacts into polymethylmethacrylate (PMMA) targets with low impedance layers were performed and compared to experiments of targets without

low impedance layers, as well as to hydrocode models under identical conditions. Impact velocities ranged from 5 km/s to 5.6 km/s, with trajectories from 30 degrees to 90 degrees above the horizontal. High-speed imaging provided documentation of the sequence and location of failure due to impact, which was compared to theoretical models. Plasticine and ice were used to construct the low impedance layers. The combination of experiments and models reveals the modes of failure due to a hypervelocity impact. How such failure is manifested at large scales can present a challenge for hydrocodes. CTH models tend to overestimate the amount of damage occurring within the targets and have difficulties perfectly reproducing morphologies; nevertheless, they provide significant and useful information about the failure modes and style within the material. CTH models corresponding to the experiments allow interpretation of the underlying processes involved as well as provide a benchmark for the experimental analysis. The transparency of PMMA allows a clear view of failure patterns within the target, providing a 3D picture of the final damage, as well as damage formation and propagation. Secondly, PMMA has mechanical properties similar to those of brittle rocks in the upper crust, making it an appropriate material for comparison to geologic materials. An impact into a PMMA target with a one-projectile-diameter thick plasticine layer causes damage distinct from an impact into a PMMA target without a low impedance layer. The extent of the final damage is much less in the target with the low impedance layer and begins to form at later times, there is little to no crater visible on the surface, and the formation and propagation of the damage is completely different, creating distinct subsurface damage patterns. Three-dimensional CTH hydrocode models show that the pressure history of material around and underneath the impact point is also different when a low impedance layer is present, leading to the variations in damage forming within the targets.

ID#	PP31D-1385
Location:	Poster Hall (Moscone South)
Time of Presentation:	Dec 16 8:00 AM - 12:20 PM

Beringian Megafaunal Extinctions at ~37 ka B.P.: Do Micrometeorites Embedded in Fossil Tusks and Skulls Indicate an Extraterrestial Precursor to the Younger Dryas Event?

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Studies of Late Pleistocene megafaunal fossils and their ancient DNA from Beringia (eastern Siberia, Alaska, and the emerged Bering Strait) indicate sharp declines in steppe bison population diversity and horse body size, extinction of the Alaskan wild ass, and local extinctions of brown bear and woolly mammoth genetic lines beginning at about 37 ka B.P. Beringia is also well known for its remarkably preserved Late Pleistocene frozen animal mummies. ^{14}C ages of these mummies are bimodally distributed, having peaks coincident with the earlier ~37 ka B.P., and ~13 ka B.P. Younger Dryas, onset extinction events. Associated with the ~37 ka B.P. event are, for example, the Berezovka mammoth, headless Selerikan horse, steppe bison "Blue Babe", and baby mammoths "Dima" and "Lyuba". Analyses of these and other mummies indicate that they died instantly, in mostly healthy condition, with gut contents and high fat reserves indicative of a late summer to autumn season. An assortment of uneaten limbs and other body parts from a variety of species have also been found. Uniformitarian death scenarios inadequately account for the lack of evidence of normal predation and scavenging. Extensive internal injuries (e.g. large bone fractures, hemorrhaging) and apparent rapid burial of the mummies also indicate that something truly unusual happened at the time of these extinction events. We have discovered what appear to be micrometeorites embedded in seven Alaskan mammoth tusks and a Siberian bison skull acquired from commercial sources. ^{14}C ages for five of these fossils have a weighted mean age of 33 ± 2 ka B.P. Laser ablation ICP-MS and XRF analyses of the particles indicate high Fe contents with compositions enriched in Ni and depleted in Ti, similar to Fe meteorites and unlike any natural terrestrial sources. Microprobe analyses of a Fe-Ni sulfide grain from tusk 2 also show that it contains between 3 and 20 weight percent Ni. SEM images and XRF analyses of a bison skull fragment show sharp-edged channels (~0.1 mm across) containing Fe sulfide material with botryoidal texture that appears to have cooled from a molten state. Multiple embedded particles are observed on only one side of the tusk and skull fossils, consistent with micrometeorites coming from a single direction. During recent visits to natural history collections in Berkeley, CA, New York City, and London, UK, embedded Fe-rich particles were uncovered in an additional 13 Alaskan bison, horse, and musk ox skulls, and a Siberian *Elasmotherium* skull. We propose that the extinctions, embedded micrometeorites, and frozen mummies contemporaneous with the ~37 ka B.P. event all resulted from an airburst (similar to the 1908 Tunguska event), or series of airbursts, across Beringia due to the breakup and deep atmospheric penetration of an Fe-Ni asteroid. The micrometeorites can be envisioned as shrapnel traveling within the blast wave(s). The instantaneous deaths, internal injuries, and possible traumatic amputations and decapitations in megafaunal mummies are consistent with blast injuries related to such a catastrophic scenario.

ID#	PP31D-1386
Location:	Poster Hall (Moscone South)
Time of Presentation:	Dec 16 8:00 AM - 12:20 PM

Evidence of four prehistoric supernovae <250 pc from Earth during the past 50,000 years

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Analysis of the radiocarbon record for the past 50 ka indicates that four supernovae exploded near Earth 44 ka (~110 pc), 37 ka (~180 pc), 32 ka (~160 pc), and 22 ka (250 pc) ago. Each SN left a unique signature in the radiocarbon record consisting of a sudden increase in atmospheric radiocarbon at the time of the initial explosion due to the arrival of γ-rays and neutrinos, followed by a much larger increase in global radiocarbon spanning centuries due to cosmic rays produced by diffusive shock in the SN remnant, and concluding with the decay of the excess global 14C produced in these events. Temporal evolution of this signature is identical for each SN as if it were a "standard candle". The ~22 ka SN is most likely the Vela SN that is known to have exploded 10-30 ka ago 250 pc from Earth. The distances of the other SNe are calculated from the relative amounts of radiocarbon produced on Earth with respect to the Vela SN assuming a 1/r2 relationship. The rate of these nearby prehistoric SNe is comparable to that expected from the more distant historical SNe observed during the past 1000 years and it is consistent with the galactic cosmic ray rate at Earth. Global radiocarbon doubled after the ~44 ka SN which exploded 110 pc from Earth, a distance consistent with the Upper Scorpius OB Association. It coincides with the advent of modern man, mutations leading to the development of type A and B blood, and major megafaunal extinctions in Southeast Asia. An exponential fit to the past 18 ka of INTCAL04 Δ14C data gives a half-life of 5700±700 yr, consistent with the half-life of 14C (5730 yr), and establishes an absolute scale of Δ14C=5±2% for T=0 in 1950. Small variations about the exponential decay curve correlate with observed changes in the strength of Earth's virtual axial dipole moment (VADM). Analysis of the energy necessary to produce the excess global radiocarbon indicates that these SNe explosions released ~$3x10^{50}$ ergs of energy into the production of cosmic rays, a value consistent with expectations. Corroborating evidence for these SNe is seen in the 10Be/9Be ratio in ocean sediments, nitrate concentrations in ice cores, and lunar cosmogenic isotope data. Nearby SNe can change comet and asteroid orbits inducing comet showers into the inner solar system and they also may eject dust clouds and shrapnel that can impact Earth. The Younger Dryas impact layer from 13 ka ago

shows an unusual chemistry. Radiocarbon analysis of carbon spherules from the YD impact layer at Gainey and various Carolina Bays yields future dates despite their stratigraphy. Charcoal from Chobot and the Carolina Bays date to <6000 yr BP a common characteristic of Paleo-Indian radiocarbon dates at Northern sites. The radiocarbon record shows a sudden increase in global radiocarbon at the time of the YD impact with a signature different from the near Earth SNe. There is no mechanism for the injection of excess radiocarbon into an impact layer unless the impacting object came directly from a recent, nearby SN where 14C is predicted to be produced at 107 times terrestrial abundance. Near Earth SNe (<300 pc) are expected every ~15 ka, and at least two nearby giant stars Betelgeuse (132 pc) and Antares (190 pc) are near the end of their lives and likely to go SN in the near future.

ID#	PP31D-1387
Location:	Poster Hall (Moscone South)
Time of Presentation:	Dec 16 8:00 AM - 12:20 PM

Geomorphology Of Possible Younger Dryas Boundary Impact Structure

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Solicited Abstract

In a previous AGU submission (AGU 2006 T41A-03) and its referenced web-based documentation (perigeezero.org), we proposed that extraterrestrial impacts were responsible for cooling at the Younger Dryas boundary, North American megafaunal extinctions, and collapse of Native American culture. Recent work by others (Firestone, et al) has added significant support to such a hypothesis.

A challenging aspect of the hypothesis involves the lack of an identifiable impact structure. As a plausible solution, our Perigee:Zero (P:Z) conjecture implicates the decaying orbits of earth-captured cometary bodies. Such impact events occur when the perigee of the orbit reaches the earth's surface - in effect Perigee = Zero. Given the relatively low velocities involved, the shallow angle of incidence and the hydrated nature of the impactors, the geological signature of proposed P:Z impact structures are uncharacteristic of cosmic impact structures. Additionally, the conjecture suggests that terrestrial material ejected from such an event would be distributed in a stylized manner.

Our analysis correlates numerous proposed P:Z ejecta material emplacements - including the Carolina bays and the Goldsboro Ridge - to a Perigee: Zero impact event that struck the Wisconsin-era ice shield at ~43°N, ~87°W. The proposed scouring action of the event is seen producing the current-day southern half of Lake Michigan. http://perigeezero.org/treatise/Proof_sets/lake_michigan/

ID#	PP31D-1388
Location:	Poster Hall (Moscone South)
Time of Presentation:	Dec 16 8:00 AM - 12:20 PM

Positive anomaly in platinum group elements and the presence of shocked diamonds: Two question marks at the Younger Dryas

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Recently, a large size impact was proposed as the cause of the global changes taking place at the Younger Dryas (YD) some 12,9 kyr ago. Impact evidence was reported in a C-rich black layer of broad geographic distribution. The impact markers consist of a large anomaly in the concentration of platinum group elements (PGE) and the presence of nanodiamonds, in particular lonsdaleite, which hexagonal structure is believed to be of shock origin. The impact is proposed to have occurred on the North American continent. A crater large enough (> 150 km) to induce a mass extinction some ~12.9 ka ago, formed in a geologically well-known area, is unlikely to have escaped detection. Therefore, an alternative hypothesis is that a cometary projectile exploded fully within the atmosphere spreading PGE and shock formed diamonds, without any target rock contribution, all around the Northern hemisphere. So far, PGE measurements failed to reproduce the elevated (> ppb) concentrations reported previously at Younger Dryas sites containing the black layer. In Lommel (Belgium) where the first study detected up to 117 ppb Ir, the Ir concentration is below the detection limit of the method (NiS fire assay + ICP-MS) used (0.06 ppb). At all sites analyzed the PGE pattern is typical of that of the continental crust. In several craters (Popigai, Ries) or at the KT boundary nanodiamonds have been reported associated with shocked materials. Several types of carbon components occur in the black layer of the Lommel section such as i) flakes reaching up to 1 μm, ii) nano particles of cubic diamond, 1 to 10 nm in size and iii) larger carbon onion-ring structures, which core can

act as a nanoscopic pressure cell leading to the formation of nanodiamond by self- compression. The Lommel nanodiamonds present in the Younger Dryas layer do resemble nanodiamonds found in carbon spherules of unknown origin previously reported in top soil from several localities in Belgium and Germany. The C stable isotopic signature measured in the C-rich black layer is clearly produced by organic matter of terrestrial origin (-29‰).

ID#	PP31D-1389
Location:	Poster Hall (Moscone South)
Time of Presentation:	Dec 16 8:00 AM - 12:20 PM

The platinum group metals in Younger Dryas Horizons are terrestrial

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2. Department of Earth Sciences, University of California, Santa Barbara, CA, USA.
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The Younger Dryas (YD) event, which began 12,900 years ago, was a period of abrupt and rapid cooling in the Northern Hemisphere whose primary cause remains unclear. The prevalent postulated mechanism is a temporary shutdown of the thermohaline circulation following the breakup of an ice dam in North America. Firestone et al. (2007) proposed that the cooling was triggered by multiple cometary airbursts and/or impacts that engendered enormous environmental changes and disrupted the thermohaline circulation. The evidence in support for this hypothesis is a black layer in North America and in Europe marking the YD boundary containing charcoal, soot, carbon spherules and glass-like carbon suggesting extensive and intense forest fires. This layer is also enriched in magnetic grains high in iridium, magnetic microspherules, fullerenes containing extraterrestrial He-3, and nanodiamonds. Whereas the nanodiamonds could be produced in an impact or arrive with the impactor, the cometary burst/impact hypothesis remains highly controversial as the YD horizon lacks important impact markers such as craters, breccias, tektites and shocked minerals. Firestone et al. (2007) contend that bulk of Ir found at the YD boundary is associated with magnetic grains. The key issue is whether this Ir is meteorite derived. We used Ir and Os concentrations and Os isotopes to investigate the provenance of the platinum group metals in the YD horizon. The *bulk* sediment samples from a number of North American YD sites (Blackwater Draw, Murray Springs, Gainey, Sheriden Cave, and Myrtle Beach) and a site in Europe (Lommel) do not show any traces of

meteorite derived Os and Ir. The [Os] = 2 to 45 pg/g in these sediments and the $^{187}Os/^{188}Os$ ratios are similar to the upper continental crustal values (~1.3), much higher than those in meteorites (0.13). Higher [Os] is observed in Blackwater Draw (= 194 pg/g). However, the Os/Ir ratio in Blackwater Draw is 5 (not 1 as expected for a meteorite) and $^{187}Os/^{188}Os$ ratio = 1.35, which remains constant above and below the YD horizon. Kennett et al. (2009) report 200 ppb of nanodiamonds and about 4 ppb of Ir in bulk sediments from Murray Springs. Since chondritic meteorites contain approximately 400 ppm of presolar nanodiamonds and about 500 ppb of osmium, simple mixing requires that the YD horizon at Murray Springs should contain about 250 pg/g of Os. However, the observed Os concentration of YD horizon at Murray Springs is only 45 pg/g and the $^{187}Os/^{188}Os$ ratio is 1.66. These observations suggest that if there was an impact that produced the nanodiamonds and dispersed them, it did not provide Os (and Ir) to the Murray Springs and other North American sites. We have so far separated and analyzed magnetic grains from Gainey and Lommel and find their [Os] and $^{187}Os/^{188}Os$ ratios consistent with a terrestrial origin. The [Os] of microspherules analyzed so far are too low to be derived from meteorites. Our analyses therefore do not support an extraterrestrial origin of the platinum metals in YD horizons from North America and Europe.

ID#	PP31D-1390
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Field-Analytical approach of land-sea records for elucidating the Younger Dryas Boundary syndrome

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Linking lonsdaleite crystals, carbon spherules and diamond polymorphs from the North American dark layers at 12.9 cal yr B.P. to a cosmic event has questioned the nature and timing of the related impact processes. A global signal should trace the invoked airshocks and/or surface impacts from a swarm of comets or carbonaceous chondrites. Here we report on the contextual analytical study of debris fall events from three reference sequences of the Younger Dyras period (11-13 ka cal BP) : (1) sand dune fields along the French Atlantic coast at the Audenge site; (2) A 10 m record of detrital/bioorganic accumulation in the southern basin of the Caspian Sea with regular sedimentation rate

(0.1 to 3 mm per year) from 14 to 2-ka BP cal; (3) the Paijan sequence (Peruvian coastal desert) offering fossiliferous fluvial layers with the last large mammals and aquatic fauna at 13 ka BP sealed by abiotic sand dunes. The three sequences display one remarkable layer of exogenous air-transported microdebris that is part of a complex time series of recurrent fine dust/wildfire events. The sharp debris-rich microfacies and its association to ashes derived from calcination of the local vegetation suggest instantaneous deposition synchronous to a high intensity wildfire. The debris assemblage comprises microtektite-like glassy spherules, partly devitrified glass shards, unmelted to partly melted sedimentary and igneous clasts, terrestrial native metals, and carbonaceous components. The later occur as grape-clustered polymers, vitrified graphitic carbon, amorphous carbon spherules with a honeycomb pattern, and green carbon fibres with recrystallized quartz and metal blebs. Evidence for high temperature formation from a heterogeneous melt with solid debris and volatile components derived from carbonaceous precursors supports an impact origin from an ejecta plume. The association of debris deposition to total firing would trace a high energy airburst with surface effects of the fireball. In contrast, microfacies and debris composition of the recurrent fine dust/wildfire events would trace a series of a low energy airburst. Their record is expressed in the Audenge sequence by a series of water-laid laminae of charred pine residues formed of carbonaceous spherules wrapped by carbonaceous polymers that includes lonsdaleite crystals as detected by high resolution in situ micro-Raman analysis. This association suggests recurrent flash forest wildfires ignited by hot spray of carbon-rich debris, followed by heavy snow falls.
The record from the Peruvian desert suggests a possible linkage between the repeated debris fall/wildfires during the Younger Dryas and the following irreversible aridity along the Peruvian cost. In contrast the Caspian record of the Younger Dryas period indicates more gradual changes, possibly buffered by the hydrological functioning of the Caspian sea in a complex region. The Audenge context offers the amplified signal needed to understand at local to global scales the spatio-temporal pattern of impact-airburst events.

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Cometary airbursts and atmospheric chemistry: Tunguska and a candidate Younger Dryas event

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We estimate atmospheric chemistry changes from ionization at the 1908 Tunguska airburst event, finding agreement with nitrate enhancement in GISP2H and GISP2 ice cores and noting an unexplained accompanying ammonium spike. We then consider the candidate Younger Dryas comet impact. The estimated NO_x production and O_3 depletion are large, beyond accurate extrapolation. A modest nitrate deposition signal exists in ice core data. The predicted very large impulsive deposition might be visible in higher resolution data.
Ammonium has been attributed to biomass burning, and found coincident with nitrate spikes at YD onset in both the GRIP and GISP2 ice cores. A similar result is well-resolved in Tunguska ice core data, but the Tunguska forest fire was far too small to account for this. Direct input of ammonia from a comet into the atmosphere is consistent with the spike for the candidate YD object, but also inadequate for Tunguska. An analog of the Haber process with hydrogen contributed by the cometary or surface water, atmospheric nitrogen, high temperatures, pressures, and the possible presence of catalytic iron from a comet could in principle divert a variable fraction of the reaction products to ammonia, accounting for ice core data in both events.

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Nanodiamonds and Carbon Spherules from Tunguska, the K/T Boundary, and the Younger Dryas Boundary Layer

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More than a dozen markers, including nanodiamonds (NDs) and carbon spherules (CS), occur in a sedimentary layer marking the onset of the Younger Dryas (YD) cooling episode at ~12.9 ka. This boundary layer, called the YDB, has been found at nearly forty locations across North

America, Europe, and Asia, although not all markers are present at any given site. Firestone et al. (2007) and Kennett et al. (2008, 2009) proposed that these markers resulted from a cosmic impact/airburst and impact-related biomass burning. Here we report features common to the YDB event, the Cretaceous-Tertiary (K/T) impact, and the Tunguska airburst of 1908. In sediments attributed to each event, we and other researchers have recovered NDs either inside or closely associated with CS, which appear to be the high-temperature by-products of biomass burning. CS range in diameter from about 500 nanometers to 4 millimeters with a mean of ~100 microns, and they typically contain NDs, including lonsdaleite (hexagonal diamonds), in the interior matrix and in the crust. To date, CS and NDs have been found in the K/T layer in the United States, Spain, and New Zealand. Similarly, CS and NDs have been found in the YDB layer in the United States, Canada, United Kingdom, Belgium, the Netherlands, Germany, and France. Thus far, every site examined contains NDs and/or CS in the K/T and YDB layers; conversely, we have yet to detect CS associated with NDs in any non-YDB sediments tested. Five allotropes of NDs have been identified in association with CS: cubic diamonds, lonsdaleite, n-diamonds, p-diamonds, and i-carbon, which are differentiated by slight variations in their crystalline structure. All allotropes have been identified using scanning electron microscopy (SEM), high-resolution electron microscopy (HREM), and transmission electron microscopy (TEM) with confirmation by selected area diffraction (SAED). Lonsdaleite is found on Earth only in three instances: (1) in the laboratory, where it is produced by shock synthesis under a high-temperature-high-pressure regime (~1000°C to 1700°C at 15 GPa) or by carbon vapor deposition (CVD) under a very-high-temperature-low-pressure regime (~13,000°C at 300 Torr) (Maruyama et al., 1993); (2) after arrival on Earth inside extraterrestrial material; and (3) as a result of high-temperature cosmic impact/airbursts. Lonsdaleite associated with CS has been found in sediments only at the K/T, the YDB, and Tunguska, consistent with the hypothesis that all three events have cosmic origins, although the nature of the impactors may have been different.

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Wildfires, Soot and Fullerenes in the 12,900 ka Younger Dryas boundary layer in North America

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The debate surrounding the late Pleistocene megafaunal extinctions in North America and the possible cause being related to an impact (asteroid or cometary) event at the Younger Dryas boundary (YDB) some ~12,900 ka, has recently been renewed with the discovery of nanodiamonds (lonsdaleite) and other diamond polymorphs in several YDB locations worldwide(1). While the discovery of lonsdaleite is certainly exciting, it is unclear whether or not this diamond allotrope would form during shock processes diagnostic of an impact event. Moreover, there are combustion related processes (e.g. CVD and anoxic combustion) that can lead to the production of nanodiamonds. Nevertheless, the presence of nanodiamonds coupled to other impact tracers (e.g. magnetic spherules, iridium) in the YDB layer suggests that these nanodiamonds may be related to an impact event.

In previous studies of some North American YDB sitesm we searched for fullerenes with trapped noble gases. Fullerenes (C60 to C200) from Clovis age sites at Murray Springs, AZ, Blackwater Draw, NM and Daisy Cave, San Miguel Channel Island, contain trapped helium and argon with isotope ratios similar to the planetary component of carbonaceous chondrites, indicative of their formation in an extraterrestrial environment. In addition, polycyclic aromatic hydrocarbons (PAHs) were also identified in the same layer along with charcoal and soot that are attributed to widespread wildfires associated with the impact event. In an effort to better understand the true nature of the nanodiamonds, we have collected some charcoal spherules related to a younger impact crater and some modern day wildfires. The results of all of these studies will be presented.

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Cold Climate Related Structural Sinks Accommodate Unusual Soil Constituents, Pinelands National Reserve, New Jersey, USA.

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Firestone and others proposed an extraterrestrial (ET) impact upon the Laurentide Ice Sheet 12,900 years ago led to abrupt climate change and left behind a distinct suite of microscopic soil markers. If so, then soil memory of such an extreme event should be apparent across a wide swath of ice-marginal North America. New Jersey's Pine Barrens has a remarkably well-preserved record of Late Pleistocene soil structures that provide snapshots of rigorous climatic episodes, the youngest of which are potential reservoirs for ET markers. Cryogenic macrostructures are fissures related to episodic temperature and moisture extremes providing excellent chronostratigraphic control - unlike soil horizons that are often affected by denudation and pedogenic modification.

Three distinct ground structures were sampled for evidence of infill-related ET markers: 1) two ground (soil) wedges (early Holocene?); 2) a younger sand-wedge cast (late-Wisconsinan?); and 3) an older sand-wedge cast (early-Wisconsinan?). Attendant host sediment and capping colluvium coversand samples were also collected for evidence of ET markers to detect potential source sinks. Our pedocomplex contained elements ranging from Miocene Cohansey Formation basement sands to early-Holocene fluvioeolian coversands. Scanning electron microscopy (SEM), transmission electron microscopy (TEM), and energy dispersive x-ray analysis (EDX) are being used to characterize soil constituents of interest. Carbon and luminescence dating are underway to provide geomorphic events timing associated with specific soil constituent trap formation. Fly ash collected from a coal-fired electrical plant 13-km distant was also examined.

Several soil constituents atypical to the local petrology as currently understood were found. Infill from two ground (soil) wedges contained ~100,000 to ~500,000 magnetic spherules/kg, 25 to 50 translucent amber-colored spherules/kg, 250 to 500 carbon spherules/kg, charcoal, and pieces of glass-like carbon. Some of these carbon spherules (~1 in 20) contained n-diamond allotrope nanodiamonds, and averaged between 2 and 60 nanometers across. Magnetic spherules were found bound within a caramel colored brittle matrix and averaged about 10 to 30 microns across, and on occasion formed raspberry-like clusters. The fly ash contained no detectable diamonds, although it did contain a few magnetic spherules. Testing of other samples is in progress.

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Rockyhock and Kimbel Carolina Bays: Extraterrestrial Impact or Terrestrial Genesis?

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Evidence for the harsh climate prevalent during the Last Glacial Maximum (LGM) are seen in topographical features visible south of the ice sheet margin in the uplands and coastal regions of the southeastern United States. Among the features attributed to ice age climate are numerous elliptical, shallow depressions called collectively Carolina Bays, hypothesized to have been formed by “blow outs” of loose sediment by the strong, sustained winds and arid, cold climate characteristic of glacial epochs (Raisz, 1934, Johnson, 1942 and Kaczorowski, 1977). This view eclipsed the 1933 proposition by Melton and Schriever, and expanded by Prouty (1934, 1953), that extraterrestrial debris produced by an aerial meteorite or comet explosion in the vicinity of the Great Lakes during the late Pleistocene formed the bays. 12,900 years ago, post-LGM warming was interrupted by a return to a glacial climate that persisted for over 1,000 years. The events precipitating the cooling, known as the Younger Dryas (YD), are the subject of debate. Recently Firestone et. al. (2007) proposed that an impact in the Laurentide ice sheet by a fragmented comet might have simultaneously initiated the YD and formed the Carolina Bays. Carbon 14 dating and pollen analysis of core samples taken from Rockyhock Bay, in Chowan County, NC, by Whitehead (1980) indicate a pre-YD genesis. However, a number of the bays have been found to contain materiel associated with extraterrestrial impacts including carbon and magnetic spherules, glass-like carbon, charcoal and nanodiamonds (Firestone, et. al. 2007). The discoveries reinvigorated the debate over the bay’s origins. Were the bays created by an impact or were they merely receptacles for impact materiel injected into the environment. If created before the YD, the bays would have experienced episodic post-formation modification due to cold, dry, windy periods alternating with warm, moist and calmer climatic conditions. Carolina Bays would thus episodically fill with wind-blown or water-borne sediment or water. Some evidence of bay history should be evident in their stratigraphy. Rockyhock Bay’s proximity to ECSU motivated the attempt to establish a broad chrono-stratigraphic context to reveal whether Whitehead’s

inferred bay-structure and age vs. depth correlation were mischaracterized. Core samples were taken from bay rim and center and a Ground Penetrating RADAR (GPR) survey was performed. Results will be compared with the cited earlier published results. Results will be compared to a similar survey performed for Kimbel Bay, near Fayetteville, NC, whose hydrologic history seems different than that of Rockyhock Bay.

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An Independent Evaluation of the Younger Dryas Extraterrestrial Impact Hypothesis

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Based on elevated concentrations of a set of impact markers at the onset of the Younger Dryas stadial from sedimentary contexts across North America, Firestone, Kennett, West, and others have argued that 12.9 ka, the Earth experienced an impact by an extraterrestrial body, an event that had devastating ecological consequences for humans, plants, and animals in the New World. In this paper, we report the results of an independent analysis of magnetic minerals and microspherules from seven sites of similar age including two previously examined by Firestone et al. We were unable to reproduce any results of the Firestone et al. study and find no support for Younger Dryas extraterrestrial impact.

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Evidence for Widespread Biomass-Burning at the Younger Dryas Boundary at 12.9 ka

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A diverse assemblage of nanodiamonds found in the Younger Dryas boundary layer (YDB) across North America is consistent with a high-temperature cosmic event at 12.9 ka. Abundance peaks in biomass-burning proxies, such as charcoal, grape-cluster soot, carbon spherules, and glass-like carbon suggest that a major, cross-continental episode of biomass-burning occurred simultaneously at the onset of the Younger Dryas (YD) cooling episode. These peaks appear contemporaneous with Greenland ice cores records that exhibit spikes in ammonium, nitrate, formate, and oxalate, which also are interpreted to represent episodes of biomass-burning. At the YD onset, the ammonium peaks in the GISP2 and GRIP ice cores are the largest such peaks reported, suggesting that the largest wildfires within the last 130 kyrs occurred at ~12.9 ka.
CHARCOAL: Recently, Marlon et al. (2009) reported analyzing sediment cores from 35 lakes widely distributed across North America. In ~90% of their cores (32 of 35), they found charcoal peaks dating to 12.9 ka ±250 yrs, and they note a particularly steep increase in charcoal influx beginning at 13.2 ka. This charcoal reached an abundance peak at ~12.9 ka, and they interpreted it as representing *"the largest and most rapid change in biomass burning during deglaciation. Burning was widespread but not continent wide."* However, they concluded that this peak is not representative of YDB fires apparently because it began at 13.2 ka and was not within ±50 yrs of 12.9 ka. We have reanalyzed Marlon's data and determined that multiple ^{14}C dating errors may have led them to reach that conclusion. Their lake records contain numerous cumulative dating uncertainties: (1) they utilized multiple, incompatible ^{14}C calibration curves, thereby introducing age uncertainties of ±175 to ±650 yrs; (2) average chronological sample resolution was about ±180 yrs, much greater than ±50 yrs; (3) the radiocarbon dates used had a mean error of ±132 yrs; (4) for the ^{14}C dates closest in age to 12.9 ka, the mean interval was >1100 yrs younger or older. Collectively, these errors make it impossible to reach conclusions about the timing of a burning episode at 12.9 ka with a certainty of ±50 yrs. Instead, we argue that the widespread wildfires they reported more likely correspond to the YD onset. Also, we analyzed cores from 39 additional lakes broadly distributed across North America and found that they exhibit a distinct collective charcoal peak at 12.9 ka within the limits of ^{14}C uncertainty. We also detected above-background concentrations of charcoal in 23 of 25 non-lacustrine continental sections tested that date to ~12.9 ka. The

existence of widespread, though not ubiquitous, charcoal plausibly supports a major cross-continental biomass-burning episode at 12.9 ka. The K/T impact layer is the only other known horizon that contains peaks in charcoal, soot, CS, and nanodiamonds, further suggesting a cosmic connection for the YDB layer.

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Climatic Control of Biomass Burning During the Last Glacial-Interglacial Transition

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Sedimentary charcoal and pollen records were used to test the hypothesis that an extraterrestrial impact at the beginning of the Younger Dryas Chonozone (YDC, 12.9 to 11.7 ka) caused widespread biomass burning in North America. Comet-theory proponents argue that continental-scale wildfires were triggered by the ET impact and are evidenced by carbon spherules, charcoal and soot found at archaeological sites across the continent. We examined charcoal accumulation rates and pollen-inferred vegetation changes in lake-sediment records during the 5000-year interval surrounding the YDC to look for evidence of continental-scale burning. None of the study sites used in the analysis are associated with archaeological sites and many are in remote, high-elevation locations where impacts from human-caused burning was probably minimal. All the records show evidence of sporadic fires throughout the late-glacial period, and together show a trend of increasing biomass burning until the beginning of the YDC, little increase during, and then increasing biomass burning at the end of the YDC. Three of fifteen of the highest-resolution records (i.e. < 50 years per sample), in which individual fire episodes are registered as charcoal peaks, show large fires around the beginning of the YDC, but the strongest evidence for widespread, synchronous fire activity during any 100-yr interval occurs at 11.7 ka, the end of the YDC. Among the potential controls of biomass burning, climate emerges as the most parsimonious explanation for the abrupt increase in biomass burning accompanying the abrupt warming at the end of the YDC through the influence of temperature on biomass productivity (and hence fuels), and fire-promoting environmental conditions. The association between increased biomass burning and the abrupt warming at the end of the

YDC is replicated in the response of a composite global biomass burning record to the 20 Greenland Interstadial events during the past 80,000 years. In conclusion, we find no evidence for widespread or synchronous wildfires in North America at the beginning of the YDC. Rather, there is strong evidence that abrupt warming leads to high fire activity at continental and larger scales.

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Fire regimes during the last glacial

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Fire regimes during the last glacial
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Sedimentary charcoal records document changes in fire regime. We have identified 67 sites which have records for some part of the last glacial and have used the 30 of these sites with better-than millennial-resolution to analyse changes in global fire regimes. Fire was consistently lower during the glacial than during the Eemian and Holocene. Within the glacial, Marine Isotope Stage (MIS) 3 is characterised globally by more fire than MIS 2. The signal for MIS 4 is less clear: there is more fire in the northern hemisphere and less fire in the southern hemisphere than during MIS 2 and 3. The records, most particularly records from the northern extratropics, show millennial-scale variability in fire regimes corresponding to the rapid climate changes associated with Dansgaard-Oeschger (D-O) cycles. Most of the D-O cycles during the last glacial and all of the Heinrich Stadials are apparent in the composite global record of the high-resolution sites: fire increases during D-O warming events and decreases during intervals of cooling. Our analyses show that fire regimes show a lagged response to rapid climate changes of ca 100-200 years in the case of D-O warming events, ca 0-100 years in the case of D-O cooling events and ca 200

years in the case of Heinrich Stadials. The strong climatic variability experienced during the glacial resulted in important changes in fire regimes even though the base level of biomass burning was less than today.